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ECOLOGICAL DISTRIBUTION OF MAMMALS IN THE TULAROSA BASIN, NEW MEXICO

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CONTENTS

Introduction 1
  Acknowledgments 2
Ecological Associations 2
  Creosote Bush Association 3
  Mesquite Association 5
  Atriplex Association 9
  Grassy Wash Association 10
  Malpais Lava Association 11
  White Sands Associations 13
Isolation and Dispersal of Mammals in the Tularosa Basin 16
  Desert Associations as Barriers to Mammals of the Desert Plain 17
  Isolation and Differentiation of Mammals on the White Sands 18
  Isolation and Differentiation of Mammals on the Malpais Lava 21
  Associations of the Desert Plain as Barriers to Mammals of the Mountains 22
Summary 23
Literature Cited 23

INTRODUCTION

THE Tularosa Basin of southern New Mexico is an ideal situation for studying the relationships of mammals to their environment. This desert, virtually isolated on three sides by mountains or hills, is an area of a few hundred square miles containing extensive nearly white gypsum dunes and a large bed of dark lava, in addition to the characteristic ecological associations of the Chihuahuan Desert.

The unique characters of the Tularosa Basin have drawn the attention of several plant and animal ecologists. Ruthven (1907) studied the ecological distribution of the reptiles and amphibians of the basin and named most of the important ecological associations. He was the first to point out, in the lizards, the tendency of some species of animals of the White Sands to be lighter in color than those in near-by desert regions. MacDougal (1908) reported on the general plant ecology of the White Sands. Dice

(1930) made a preliminary survey of the ecological distribution of the mammals of the basin and adjacent mountains. His discovery of an endemic, pale race of mammals on the White Sands and two endemic dark races on the lava bed (Dice, 1929) stimulated further work in these interesting areas. Bradt (1932) studied the mammals of the lava bed, Benson (1932, 1933) made an excellent and extensive study of the color of the mammals of the White Sands and dark lava bed, and Emerson (1935) made a reconnaissance study of the plant ecology of the White Sands.

I spent October, November, and a part of December, 1938, trapping breeding stocks of *Peromyscus* in the Tularosa Basin. Extensive trapping in several ecological associations resulted in an increase in the number of species of mammals known to inhabit several of the associations and added to our knowledge of the relative abundance of the several species. In March, April, and May, 1940, an intensive study of small mammal populations in the mesquite association was made, and a short time was spent investigating other associations. An annotated list of the mammals of the Tularosa Basin (Blair, 1941*a*) gives the locality data on which the present report is based.

These intensive investigations have resulted in the accumulation of more knowledge about the ecological distribution of the mammals of the Tularosa Basin than is available for any other desert area in North America. Much remains to be done in the study of the Tularosa Basin, particularly on the White Sands. Nevertheless, the data now available afford a rather comprehensive picture of mammalian distribution in the Tularosa Basin.

Acknowledgments

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Tom Charles, Johnwill Faris, and George Sholly, of the National Park Service, rendered many courtesies while I was working at the White Sands National Monument. Ranchers Charles Bonnell, Gerald Champion, and Sam McNatt kindly gave me permission to trap on their ranches. I am obliged to C. L. Lundell, of the University of Michigan Herbarium, for identifying a grass that was collected in 1938. The plants that were collected in 1940 were kindly identified by A. L. Hershey, of the New Mexico State College. My wife, Fern Ann Blair, accompanied me on the trips and acted as field assistant.

ECOLOGICAL ASSOCIATIONS

An ecological association, as here defined, includes all of the plants and animals occurring together in a relatively stable environment. The mammals are, however, the only animal constituents treated in the present report.

There are four ecological associations on the desert plain of the Tularosa Basin. The creosote bush, mesquite, and atriplex associations occupy broad belts lying parallel to the mountain front and are encountered in that order as one proceeds from the base of the mountains to the center of the basin. The grassy wash association cuts across the other associations of the desert plain. The malpais lava bed has been described as one ecological association. Four associations are recognized in the White Sands. Several isolated, rocky buttes in the Tularosa Basin are not considered here, because no study has been made of their ecological associations.

In the treatment of individual associations an estimate of the average abundance of each species of mammal, based on my records and those of previous investigators, is given by means of a numerical scale containing five classes. These classes are: I (rare), II (few), III (intermediate in abundance), IV (common), and V (abundant). Classification of a species in a given association in one of these groups indicates its relative abundance as compared to its abundance and the abundance of other species in the other associations of the Tularosa Basin.

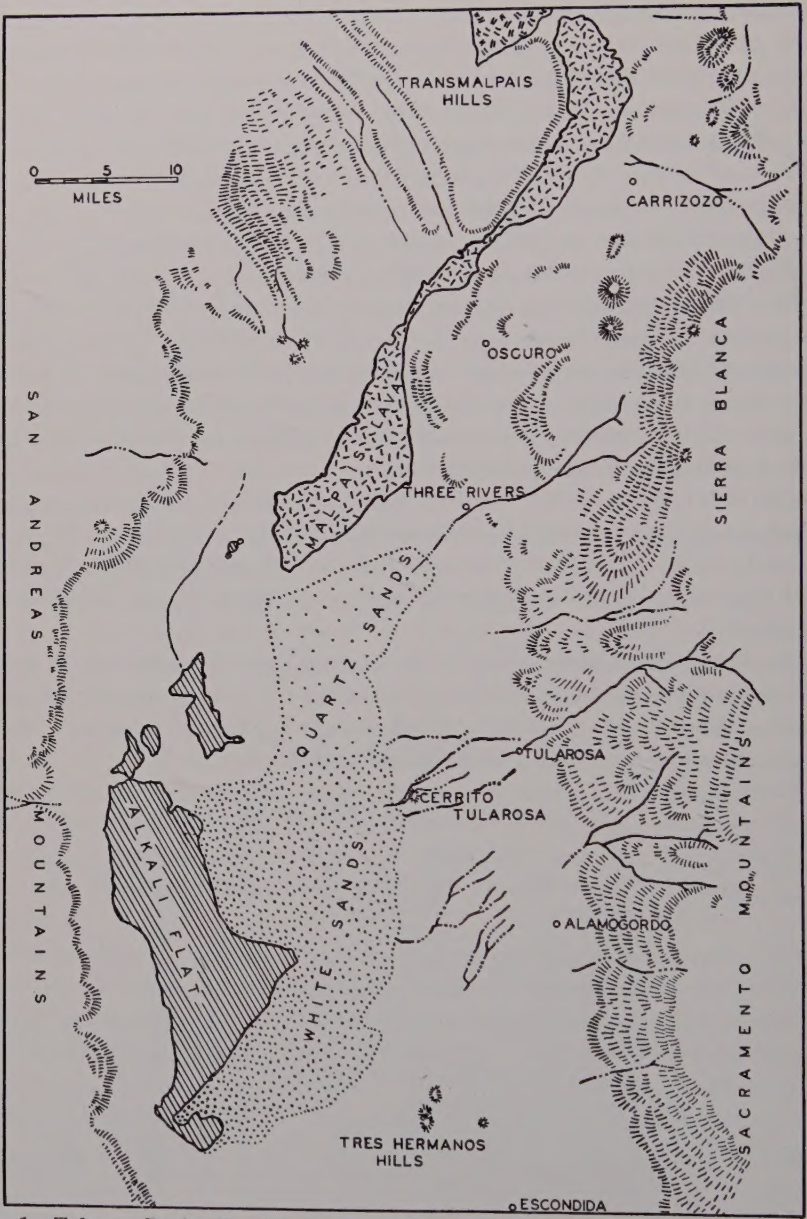
The estimated order of relative abundance of the mammals in each ecological association is given in the associational list of species. The species that is believed to be the most abundant one in the association heads the list. The other species follow in the probable order of their relative abundance.

The taxonomic arrangement of the mammals has been treated in a previous report (Blair, 1941*a*). Nomenclature of the plants, except grasses, is based on Wooton and Standley (1915), except for known changes. For the grasses, Hitchcock (1935) is used as an authority.

Creosote Bush Association

Mammals	Abundance
Perognathus penicillatus eremicus	V
Dipodomys merriami ambiguus	IV
Lepus californicus texianus	III
Sylvilagus audubonii minor	II
Onychomys torridus torridus	II
Neotoma micropus canescens	II
Thomomys baileyi tularosae	II (local)
Peromyscus maniculatus blandus	I
Dipodomys ordii ordii	I
Citellus variegatus grammurus	I
Peromyscus truei truei	I
Canis latrans subsp.	I

The creosote bush association was named and figured by Ruthven (1907), who studied it on the "alluvial slopes east of Alamogordo." Dice (1930) collected mammals in it near Alamogordo (Map 1). I trapped in this association about three miles north of Tularosa from October 8 to 12, 1938 (approximately 2000 trap nights). Pocket gophers were trapped in this association about two miles north of Alamogordo on February 29, 1940.



Map 1. Tularosa Basin, New Mexico (based largely on Meinzer and Hare, 1915, Pl. 1).

The creosote bush association occupies the alluvial slopes along the base of the Sacramento Mountains in the Tularosa Basin. Therefore, there is a more or less continuous belt of this association, often several miles wide, which is bounded on the one side by the associations of the lower mountain slopes and on the other by the mesquite association. The creosote bush (*Larrea tridentata*) characterizes this association, and so far outnumbers other species of plants that they are scarcely noticeable. Herbs are, for the most part, conspicuously absent. Dice mentioned a small mustard as numerous in early July. The creosote bushes are generally separated by barren soil. Scattered mesquites (*Prosopis glandulosa*) occur in the association. In a few places creosote bush and mesquite are present in approximately equal abundance, but, usually, the creosote bush and mesquite associations are sharply defined.

The soil of the creosote bush association is highly variable in texture and color. Coarse sand predominates in many places, and in general the soil particles are coarser than they are in the mesquite association. Near the upper limits of the association, small rock fragments in some places litter the surface of the soil. The soil varies from dark red to light gray.

Two of the species of mammals recorded from the creosote bush association, *Citellus variegatus* and *Peromyscus truei,* are mostly limited to the rocky associations of the near-by mountain slopes and occur only rarely (class I) in the creosote bush association. All other mammals recorded from this association are of species that range widely through the desert associations of the Tularosa Basin. One species, *Thomomys baileyi,* is present in scattered, local colonies in the creosote bush, mesquite, and atriplex associations. The others, with the exception of *Perognathus penicillatus* and *Dipodomys merriami,* were notably scarcer in the creosote bush association in 1938 than they were in the mesquite association. The two exceptions to this rule (*Perognathus,* class V, and *Dipodomys,* class IV) made up the greatest bulk of the population of the creosote bush association in 1938.

Three species, *Neotoma micropus, Peromyscus maniculatus,* and *Dipodomys ordii,* were remarkably scarcer here than in the mesquite association. The difference in mammalian abundance in the two associations possibly is due in part to differences in the amount of available food. The mesquite plant, in some form or another, affords a food supply throughout the year. The creosote bush apparently furnishes food for the small mammals only in the form of seeds. Except when the autumn crop of creosote bush seeds is available, food for small rodents must be scarce in this association.

Mesquite Association

Mammals	Abundance
Dipodomys merriami ambiguus	V
Dipodomys ordii ordii	V
Perognathus penicillatus eremicus	V
Peromyscus maniculatus, blandus	V
Neotoma micropus canescens	IV
Onychomys torridus torridus	III
Citellus spilosoma major	III

Mammals	Abundance
Sylvilagus audubonii minor	III
Lepus californicus texianus	III
Peromyscus leucopus tornillo	III
Onychomys leucogaster ruidosae	II
Thomomys baileyi tularosae	II (local)
Reithrodontomys megalotis megalotis	II (local)
Peromyscus eremicus eremicus	II
Sigmodon hispidus berlandieri	I
Perognathus flavus flavus	I
Neotoma albigula albigula	I
Mus musculus	I
Cynomys ludovicianus	I (local)
Citellus variegatus grammurus	I
Canis latrans subsp.	I
Odocoileus sp.	I
Lynx sp.	I

Ruthven (1907) first named and described the mesquite association in the vicinity of Alamogordo. Dice (1930) studied its mammals near Alamogordo, and Benson (1933) collected mammals in an area of mesquite on red sand near Escondida. In 1938, I trapped mammals in this association about three to four miles south of Alamogordo from October 11 to 20 and from October 23 to 30, a total of approximately 7000 trap nights. An area of mesquite association on quartz sand about thirteen miles west of Tularosa was trapped on October 3 and from November 5 to 15, a total of approximately 4000 trap nights. An intensive study was made of the small mammal population on selected plots in the mesquite association about three miles south of Alamogordo from March 4 to May 24, 1940. These studies have provided more information about the mammals than is available for the mammals of any other association of the region, not excluding the more spectacular malpais lava and White Sands associations.

The mesquite association is markedly different at each of the three places it has been studied: near Alamogordo, where Dice and I worked; on the quartz sands, where I trapped; and on the red sands near Escondida, where Benson collected.

Near Alamogordo, the mesquite achieves a more luxuriant growth than anywhere else in the Tularosa Basin. Over an area of several square miles, lying in a strip between the creosote bush association and the atriplex association, the mesquite is the most abundant and the most conspicuous plant. The mesquite so dominates this association that all of the other plants could be removed without altering materially the appearance of the vegetation. The habit of growth of the mesquite varies greatly in this area. Some mesquites constitute small trees ten to fifteen feet in height, others form dense shrubby masses of varying heights, and yet others comprise extensive areas of closely spaced, short, relatively straight mesquite stems, usually less than two feet in height. The spacing of the mesquite bushes and clumps of bushes is highly variable. In some places more or less open thickets are formed. In most sections, however, extensive areas of barren soil intervene between the mesquites. A few scattered shrubs of other species, notably crucifixion thorn (*Koeberlinia spinosa*) and atriplex (*Atriplex canescens*) are present. Herbs are scarce. In April and May of 1940, *Lepidium alyssoides* was the most abundant herb. Four others, *Astragalus nuttallianus, Verbena wrightii, Gilia pumila,* and *Sophia* species, were scarce and local. The soil is relatively fine and predominantly grayish. Wind-blown sand and dust have accumulated around many of the mesquite clumps and built up mounds from a few inches to two or three feet high. Some of the mesquite clumps are without such mounds.

The area of mesquite association in the quartz sand region about thirteen miles west of Tularosa is very limited in extent. It covers at most one or two square miles. The mesquite clumps are much smaller and generally more scattered than near Alamogordo. *Atriplex* also occurs here. The soil is very fine and considerably gypseous. The surface of the soil is thinly crusted, due to the presence of gypsum, and is light gray. There is a slight accumulation of black alkali in some places.

The mesquite area trapped by Benson near Escondida is part of an extensive area of mesquite that extends south to Texas and nearly across the central Tularosa Basin on well-developed dunes of light red or orange sand. This area comprises several hundred square miles and is the largest unit of mesquite association in the basin. The mesquites grow extensively over the tops of the dunes. Grass and other herbs are more abundant than in the other areas of mesquite in the Tularosa Basin. No study of the vegetation of these dunes has been made. Benson reported that *Gilia longiflora* was an important food item in October and the only common annual in bloom at that time. The sand dunes of this association and the greater abundance of herbs distinguish it from the mesquite association near Alamogordo and west of Tularosa. Possibly it should be recognized as a distinct association, but until a more detailed study can be made it is convenient to include it in the mesquite association.

Twenty-two species of mammals have been recorded from the mesquite association, and one other species is reported to occur there. In this association, as represented at Alamogordo, five species account for the bulk of the mammalian population. These are *Dipodomys merriami, Dipodomys ordii, Perognathus penicillatus, Peromyscus maniculatus* (all class V), and *Neotoma micropus* (class IV). Five species (from *Onychomys torridus* through *Peromyscus leucopus* in the list at the beginning of the section) are considerably less abundant (class III) in the mesquite association than the above mentioned ones. All but one of these are widely distributed in the ecological associations of the basin, and are not numerous in any of them. The fifth species, *Peromyscus leucopus,* is mostly a constituent of the grassy wash association, where it ranks in class V.

Thirteen species of mammals are rare or local in occurrence in the mesquite association. Of these, *Thomomys baileyi* is present in colonies of considerable size, but the colonies are scarce. Another, *Reithrodontomys megalotis,* apparently is unevenly distributed or sporadic in the mesquite association, for, although Dice recorded thirty specimens taken in 1927, I caught none in two seasons of extensive work. This species becomes abundant (class V) in the grassy wash association. One species, *Sigmodon hispidus,* is largely restricted to the grassy wash association, where it is common (class IV). Two rare species of the mesquite association, *Perognathus flavus* and *Cynomys ludovicianus,* are relatively rare (class I or II) in all of the associations of the basin. The former is more abundant in the grassy wash (class II) than in the mesquite association (class I), and the latter has been partly destroyed by poisoning operations.

Three species that occur rarely or sporadically in the mesquite association are largely restricted to the rocky associations of the mountain slopes. One of the three, *Peromyscus eremicus,* was taken in the mesquite association in the fall of 1938, but it was not found there in the spring of 1940. Another, *Neotoma albigula,* was trapped there in 1940, but not in 1938. Dice found the third species, *Citellus variegatus,* to be scarce in the mesquite association in 1927, and I did not observe it there. Tracks of *Odocoileus* species were observed once in the mesquite association in the spring of 1940. The last species in the mesquite association list (*Lynx* species) was recorded by Dice as being reported to occur in the association.

The mesquite association about thirteen miles west of Tularosa was occupied by the species of mammals that were commonest in the same association near Alamogordo. Small mammals, however, were scarcer than they were in the Alamogordo mesquite. Three species, *Dipodomys merriami, Dipodomys ordii,* and *Peromyscus maniculatus,* made up the bulk of the small mammal population. Two species, *Perognathus penicillatus* and *Neotoma micropus,* were much scarcer at this station than at Alamogordo. *Lepus californicus* appeared to be about as plentiful as at Alamogordo. *Peromyscus leucopus* was scarce, for only one individual was caught. Only *Peromyscus eremicus* of the four characteristic mountain slope species recorded from the same association at Alamogordo was taken at this station. Although fewer species were recorded at this station than at Alamogordo, more extended trapping probably would reveal the presence of other rare species in this association. The sparse distribution and small size of the mesquite clumps probably accounts, in part at least, for the small mammals being scarcer here than in the Alamogordo mesquite.

The results of Benson's trapping in the mesquite association on the Escondida red sands point to marked differences from the other areas of mesquite association in the proportions of the several species recorded there. *Dipodomys ordii* apparently was the most abundant small mammal, followed rather closely by *Onychomys leucogaster,* which was rare at the other stations. *Sylvilagus audubonii* and *Lepus californicus* were recorded as numerous. *Dipodomys merriami* apparently was much scarcer than at the other stations in the mesquite association. *Peromyscus leucopus* was taken, but *Peromyscus maniculatus* was not. The striking differences in numbers between the sand dune mesquite association population and the populations of the same association on relatively level compact soils probably are attributable largely to these soil differences. The two most abundant species at the Escondida station usually are associated with sandy soil, although both occur away from sand.

Atriplex Association

Mammals	Abundance
Dipodomys merriami ambiguus	III
Dipodomys ordii ordii	II
Peromyscus maniculatus blandus	I
Citellus spilosoma major	I
Lepus californicus texianus	I
Thomomys baileyi tularosae	I (local)
Sylvilagus audubonii minor	I
Dipodomys spectabilis baileyi	I

Ruthven (1907) named and figured the atriplex association from his studies in the area between Alamogordo and the White Sands. Dice (1930) collected mammals in this association about nine miles west of Alamogordo. His is the only study of the mammals of this extensive association. In the spring of 1940, I trapped pocket gophers in this association about eleven miles southwest of Alamogordo.

The atriplex association occupies an extensive area in the Tularosa Basin between the mesquite association and the White Sands. The saltbush (*Atriplex canescens*) is the most abundant and most conspicuous shrub. Other plants recorded by Dice from this association are crucifixion thorn, prickly pear (*Opuntia* species), and bunch grass (*Sporobolus* species). I collected five species of plants in addition to saltbush about twelve miles southwest of Alamogordo: the joint fir (*Ephedra torreyana*), peppergrass (*Lepidium alyssoides*), blue curls (*Phacelia corrugata*), sand verbena (*Abronia angustifolia*), and a mallow (*Sphaeralcea* species). All of these, however, appeared to be relatively scarce and local in the atriplex association. This association occurs on predominantly flat land. The soil is highly alkaline and is mostly light gray.

All of the mammals recorded from the atriplex association, with the exception of *Dipodomys spectabilis,* are characteristic species of the mesquite association. They are, however, much scarcer in the atriplex than in the mesquite association.

Grassy Wash Association

Mammals	Abundance
Peromyscus leucopus tornillo	V
Reithrodontomys megalotis megalotis	V
Peromyscus maniculatus blandus	V
Sigmodon hispidus berlandieri	IV
Sylvilagus audubonii minor	III
Perognathus flavus flavus	II
Dipodomys merriami ambiguus	II
Dipodomys ordii ordii	II
Lepus californicus texianus	I
Neotoma micropus canescens	I
Peromyscus eremicus eremicus	I
Perognathus penicillatus eremicus	I
Neotoma albigula albigula	I
Peromyscus nasutus nasutus	I
Peromyscus truei truei	I
Onychomys leucogaster ruidosae	I
Notiosorex crawfordi crawfordi	I

Desert washes and ditches that transect the creosote bush, mesquite, and atriplex associations of the Tularosa Basin generally have dense growths of coarse grasses and numerous herbs. There also are scattered plants characteristic of the adjacent mesquite and creosote bush associations. Irrigation ditches and drainage ditches along railways have similar vegetation and are included in this association. The association was trapped extensively in the fall of 1938 from a point about three miles north of Tularosa nearly to Three Rivers, from November 22 to December 1 and from December 3 to 9, a total of approximately 6000 trap nights. In March, 1940, an area about three miles southwest of Alamogordo was trapped for several nights. The alkali meadow community described by Dice (1930) apparently should be included in this association.

The plants of this association have not been carefully studied. During both of my visits to the basin the herbs were not in condition to be identified. Coarse bunch grasses are the most important feature. Near Tularosa the Mexican gourd (*Cucurbita foetidissima*) is an important plant. The vines cover extensive areas, and the seeds of this gourd are an important source of food for small mammals. A few mesquites, creosote bushes, and saltbushes occur. In the area he studied Dice mentioned ''a fairly thick stand of tall grasses, some herbs, and a few scattered low shrubs.''

Seventeen species of mammals have been recorded from the grassy wash association. Four species, *Peromyscus leucopus, Reithrodontomys megalotis, Peromyscus maniculatus* (all class V), and *Sigmodon hispidus* (class IV), comprise the bulk of the population. It is particularly interesting that here small mammals of the family Cricetidae are the most abundant species, while in the other associations of the basin mammals of the family Heteromyidae tend to predominate in numbers. The cottontail (*Sylvilagus audu-*

bonii), class III, and a pocket mouse (*Perognathus flavus*), class II, become more abundant here than in any other association of the basin.

Eleven species are relatively rare (class I and II) in the grassy wash association. Six of these, *Dipodomys merriami, Dipodomys ordii, Lepus californicus, Neotoma micropus, Perognathus penicillatus,* and *Onychomys leucogaster,* are characteristic inhabitants of the adjacent associations of the desert plain and probably range from those into this association. A shrew (*Notiosorex crawfordi*) is recorded in the basin only from this association.

Four of the species that are relatively rare in the grassy wash association, *Peromyscus eremicus, Neotoma albigula, Peromyscus nasutus,* and *Peromyscus truei,* are characteristic inhabitants of rocky, mountain slopes, where they usually are abundant.

Malpais Lava Association

Mammals	Abundance
Perognathus intermedius ater	IV
Peromyscus nasutus griseus	III
Peromyscus eremicus eremicus	III
Neotoma albigula melas	III
Citellus variegatus tularosae	II
Peromyscus truei truei	II
Pipistrellus hesperus maximus	II
Sylvilagus audubonii minor	I
Lepus californicus texianus	I
Neotoma mexicana atrata	I
Citellus interpres	I
Spilogale leucoparia	I
Eutamias cinereicollis canipes	I
Dipodomys spectabilis baileyi	I
Antrozous pallidus pallidus	I
Lynx rufus baileyi	I

Recorded from the Edge of the Lava

Perognathus flavus flavus
Dipodomys ordii ordii
Neotoma micropus canescens
Reithrodontomys megalotis megalotis
Peromyscus leucopus tornillo

The malpais lava association of the Tularosa Basin was named and figured by Dice (1930), who (1929) named two dark races of mammals from the malpais. The mammals were studied by Bradt (1932) and also by Benson (1933), who (1932) described two dark races of mammals from the malpais. I trapped this association about four miles west of Carrizozo on the nights of October 21 and 22, 1938, and about five miles west of Oscuro for a few nights in late April and early May, 1940.

The Tularosa malpais or lava bed lies in the northern part of the basin. The lava flow is more than forty miles long and varies in width from less than one mile to about six miles. Dice has given a general description of the malpais lava association near its southern end. He noted that, "there is a sparse growth of mesquite, several kinds of cacti, some unidentified shrubs, and a very little grass.'' Benson likewise gave a general description of the association and pointed out that the juniper (*Juniperus monosperma*) is the dominant plant at the northern end of the lava bed and that mesquite and creosote bush are the chief plants at the southern end. No adequate study of the plants of this association has been made. I noted that the vegetation seemed to be in a much more normal condition west of Oscuro than west of Carrizozo and at the southern end of the bed, where there was evidence of intensive grazing by goats and cattle. The vegetation on the lava bed west of Oscuro probably is representative of the natural vegetation of the malpais, except at its northern end, where junipers predominate.

West of Oscuro, the principal plants of the relatively level, more or less unbroken lava surfaces are snakeweed (*Gutierrezia* species), woolly groundsel (*Senecio longilobus*), purple dahlia (*Parosela formosa*), cholla cactus (*Opuntia* species), yucca (*Yucca* species), streptanthus (*Streptanthus valida*), saltbush (*Atriplex canescens*), rattail cactus (*Opuntia leptocaulis*), and a grass that could not be identified at the season of field work. On the level surfaces, these plants grow in small crevices in the lava, where slight quantities of soil have accumulated.

The plants of the level lava surfaces also grow on rough, broken lava, in lava sinks, or on cliffs, where an additional conspicuous plant is a sumac (*Rhus microphylla*). Red salvia (*Salvia henryi*) also grows in these places. A few mesquites grow on both the broken and relatively unbroken lava surfaces.

Other plants identified from the malpais lava association west of Oscuro include bitterweed (*Actinea mearnsii*), borage (*Cryptanthe crassisepala*), erigeron (*Erigeron* species), Apache plume (*Fallugia paradoxa*), blue curls (*Phacelia caerulea*), clammy weed (*Polanisia* species, probably *uniglandulosa*), bladderpod (*Lesquerella* species), tansy mustard (*Sophia halictorum*), and verbena (*Verbena* species, probably *wrightii*). This list of plants undoubtedly is far from complete, being representative of only one season of the year. It includes, however, the species that characterize the association throughout most of the year and indicates that the malpais lava association probably supports a greater variety of plant life than any other association of the Tularosa Basin.

The physical features of the lava bed already have been adequately described by Meinzer and Hare (1915), by Dice (1930), and by Benson (1933). Perhaps emphasis should be placed on the probable importance of lava sinks, as represented west of Oscuro. Some of these are twenty to thirty feet deep and lead into small caves beneath the lava. The temperature in these sinks and caves is much more even than on the surface of the bed. Many of the deep, well-protected sinks and caves are moist at the bottom, and such mesic animals as craneflies, which probably could not exist on the surface of the lava, were observed in some of them. On the hottest days, when the surface of the lava was nearly unbearable because of the absorption of heat by the dark rock, the sinks were pleasantly cool.

Twenty-one species of mammals have been recorded from the malpais lava association, but five of them, *Perognathus flavus, Dipodomys ordii, Neotoma micropus, Reithrodontomys megalotis,* and *Peromyscus leucopus,* apparently range only into the edge. The five species that have been recorded only from the edge of the lava bed are characteristic inhabitants of other associations of the Tularosa Basin.

Five species, *Perognathus intermedius* (class IV), *Peromyscus nasutus, Peromyscus eremicus,* and *Neotoma albigula* (all class III), and *Citellus variegatus* (class II), are the most abundant forms in the malpais lava association and apparently range over the entire lava bed. Endemic, dark races of all of these except *Peromyscus eremicus* have been described and named. The population of *Peromyscus eremicus* on the malpais lava is highly variable, as Benson (1933) already has pointed out. Some individuals are dark; others are light.

The canyon bat (*Pipistrellus hesperus*) was found by Dice to be abundant at the southern end of the lava bed, and it is to be expected that it ranges over the entire association. Ten species of mammals appear to be relatively rare in this association. A dark endemic race of one of these, *Neotoma mexicana,* has been described. The one specimen of another, *Eutamias cinereicollis,* collected by Benson (1933) was stated by him to be dark.

White Sands Associations

Mammals	Abundance
Range Over the Entire Area	
Geomys arenarius brevirostris	IV
Perognathus apache gypsi	III
Peromyscus maniculatus blandus	III
Citellus spilosoma major	III
Dipodomys ordii ordii	II
Dipodomys merriami ambiguus	II
Perognathus flavus flavus	I
Lepus californicus texianus	I
Neotoma micropus leucophaea	I
Canis latrans subspecies	I
Vulpes macrotis neomexicana	I
Antilocapra americana subspecies	I
Erethizon epixanthum subspecies	I
Odocoilus species	I

Recorded Only from the Edge

Onychomys leucogaster ruidosae
Perognathus penicillatus eremicus
Onychomys torridus torridus
Reithrodontomys megalotis megalotis
Sylvilagus audubonii minor
Cratogeomys castanops lacrimalis
Taxidea taxus berlandieri
Dipodomys spectabilis baileyi
Cynomys ludovicianus arizonensis

The White Sands area was figured by Ruthven (1907), who named one ecological association, the sumac-yucca association. Dice (1930) studied the mammals of the sumac-yucca association at the edge of the White Sands. He named another association, the grama grass-joint fir association, but did not study its mammals. I trapped in the interior of the White Sands from November 16 to 20, 1938 (approximately 2000 trap nights). This station is in section 19, township 17 south, range 7 east on the Point of Sands quadrangle. It is about four miles from the eastern edge of the White Sands and is representative of the interior of the sands. From observations at this station, it seems desirable to name two ecological associations in addition to the two that previously have been recognized in the White Sands. Both of these occupy the valleys between the dunes and will be designated, respectively, the wet valley and dry valley associations. In 1940 I trapped briefly in the interior and near the edge of the White Sands.

Benson (1933) made an extensive study of the mammals of the White Sands, but he was concerned primarily with color variation rather than ecological distribution. His work on the White Sands was limited to three stations on the eastern edge. MacDougal (1908: 11) gave a general description of the vegetation of the White Sands and a chemical analysis of the gypsum "sand." Emerson (1935) made a general survey of the plant ecology of the White Sands, but he did not investigate the distribution of plant associations in the area. As a matter of fact, no detailed study of the separate ecological associations of the White Sands has been made, although a considerable amount of work has been done on the entire area as a biotic unit. Consequently, it seems best for the present to characterize the recognizable ecological associations as adequately as possible and to discuss the mammalian fauna of the entire White Sands area as a unit.

The sumac-yucca association occurs on many of the gypsum dunes of the White Sands. There is, however, no vegetation on many of the active dunes, particularly in the interior of the area. On the other dunes, the density of the vegetation varies greatly. The plant cover is relatively heavy on the more or less stable dunes near the edge of the White Sands, where there are numerous annuals in addition to the seven herbaceous species that Emerson (1935: 232) found able to elongate and thus keep above the encroaching sand. These last, which include *Ephedra torreyana, Yucca elata, Populus wislizeni, Atriplex canescens, Rhus emoryi, Poliomintha incana,* and *Chrysothamnus latisquameus,* because of their peculiar adaptability, extend into the interior of the White Sands, where they are virtually the only plants of the sumac-yucca association. The vegetation usually is sparse on the interior dunes, in contrast with its relative thickness on the peripheral dunes.

The grama grass-joint-fir association occupies the valleys between the dunes near the edge of the White Sands. Most of the sixty-two species of plants recorded by Emerson (1935: 230) from the White Sands occur in this association, and most of them apparently are limited to it. There is an excellent ground cover of grama grass (probably mostly *Bouteloua breviseta,* recorded from the White Sands by Emerson, 1935). There are scattered, small thickets of sumac (*Rhus emoryi*). The gypsum is encrusted in these valleys.

The wet valley association occupies low valleys between the dunes in the interior of the White Sands, where the water table is near the surface. The surface of the gypsum soil is encrusted and usually moist. Water undoubtedly stands in these valleys at some times. The vegetation grows on small hummocks projecting above the general level of the valleys. The principal vegetation consists of a coarse bunch grass (possibly Indian rice grass, *Oryzopsis hymenioides,* which was recorded from the interior of the sands by Emerson) and joint fir (*Ephedra torreyana*).

The dry valley association occupies relatively dry valleys in the interior of the White Sands. The soil is not encrusted, but is made up of gypsum particles similar to those that comprise the dunes. The principal plant of this association is prairie beard grass (*Andropogon scoparius* var. *neomexicanus*). This, with yucca (*Yucca elata*), makes up the bulk of the vegetation.

Twenty-three species of mammals have been recorded from the White Sands, but only eleven of these are known to range into the interior of the sands. A pocket gopher (*Geomys arenarius*), class IV, probably is the most abundant mammal of the White Sands. The wet and dry valley associations of the interior are literally undermined by the tunnels of this mammal. It is abundant in the grama grass-joint fir association of the periphery, but is relatively rare in the sumac-yucca association. Three other species, *Perognathus apache, Peromyscus maniculatus,* and *Citellus spilosoma* (all class III), are listed in the order of probable abundance. All of these live in all of the ecological associations, but in the interior they are more numerous in the wet and dry valley associations than in the sumac-yucca association. At the periphery of the area they all probably exceed *Geomys* in abundance, but if the entire population of the White Sands is considered *Geomys* probably leads in numbers. One of these species, *Perognatus apache,* is represented on the White Sands by an endemic, pale race, *gypsi.* Another, *Citellus spilosoma,* is paler and has larger white dorsal spots than others of the same species living in the mesquite association near Alamogordo (Blair, 1941*b*). The pocket gopher, *Geomys arenarius,* is represented by the endemic race *brevirostris,* which is not notably pale.

Three species of mammals, *Dipodomys ordii* and *Dipodomys merriami* (class II) and *Perognathus flavus* (class I), are more numerous at the edge of the White Sands than they are in the interior, where they are mostly limited to the dry valley association. Two species of carnivores, *Canis* *latrans* and *Vulpes macrotis,* are present in the interior of the sands as well as at the edge. *Lepus californicus* and *Neotoma micropus* range into the interior, but they are rare there as well as at the periphery. The latter is represented in the White Sands by the endemic race *leucophaea* (Goldman, 1933), which is described as being paler than *canescens.*

Some of the nine species of mammals recorded from the edge of the White Sands possibly will be found to range into the interior. Three other species undoubtedly are rare or transient in the White Sands. Dice reported *Antilocapra americana* from the area. I am at a loss to explain the origin of remains of *Erethizon epixanthum* that were found in 1940. The deer tracks that Ranger George Sholly reported probably were made by an individual from the San Andres Mountains, which lie west of the White Sands.

ISOLATION AND DISPERSAL OF MAMMALS IN THE TULAROSA BASIN

Isolation and natural selection appear to be the most important factors involved in the formation of local races of southwestern mammals (see Dice and Blossom, 1937 : 116 ; and Benson, 1933 : 56). Ecological isolation in the Tularosa Basin tends to break some of the species of mammals into numerous relatively small, more or less isolated population units. In these units the evolution of local races through natural selection may be accelerated. In addition, differentiation may occur in small populations through random fixation of genes (see Dobzhansky, 1941 : 168).

The tendency for small, partly isolated populations to differentiate is inhibited by the interchange of individuals between the several populations. This interchange acts to maintain the uniformity of the entire population of the species (see Dobzhansky, 1941 : 334). Wright (1931 : 126) has devised a formula for measuring the effectiveness of migration (dispersal) in retarding differentiation in partly isolated populations. As he points out, the theoretical case on which the formula is built must be much qualified before it is applicable to the conditions that actually obtain in natural populations. He does make the general statement, however, that, "it would appear that an interchange of the order of thousands of individuals per generation between neighboring subgroups of a widely distributed species might well be insufficient to prevent a considerable random drifting apart in their genetic constitutions." It is to be noted that he is speaking here of random divergence. With selection in different directions taking place in each of two neighboring populations, differentiation could be accomplished with an even greater interchange of individuals. Dice and Blossom (1937 : 116) cite instances of differentiation occurring presumably through natural selection though there was no apparent physical barrier to interbreeding.

Of importance in ecological isolation in the Tularosa Basin is the fact that the mammals of the region, as represented by nine species that have been studied, have home ranges that are occupied over a relatively long period of time (Blair, in press). The existence of these home ranges, each comprising a few acres, helps to localize the individual mammals and thus retards the spread of hereditary characters through the entire population. Occasional changes of home range occur, and movements of as much as one-third of a mile sometimes are made. These movements accelerate the spread of inherited characters throughout the population. With these observations in mind the possible role of ecological isolation in the differentiation of local races in the Tularosa Basin will be considered.

Desert Associations as Barriers to Mammals of the Desert Plain

The grassy wash and mesquite associations of the desert plain both include a considerable number of species of small mammals. Several species are abundant in these associations. It is evident then that these associations provide favorable ecological conditions for these species. The creosote bush and atriplex associations, on the other hand, have relatively few species of mammals, and most of the species are scarce in these associations. This scarcity seems attributable to the limited supply of food and cover available. The creosote bush and atriplex associations, being ecologically unfavorable to most small mammals, act as more or less effective barriers to the interchange of individuals and genes whenever they intervene between areas of the other associations.

The grassy wash association, because it is limited to desert washes and ditches, is discontinuously distributed in the Tularosa Basin. Since the washes cut across the belts of creosote bush and mesquite associations, small areas of grassy wash association comprising only a few acres to a few hundred acres may be completely surrounded by one or both of these other associations. Neighboring areas of grassy wash association may be separated by from less than one mile to several miles of other associations. Near Tularosa the isolation from one another of successive desert washes has ceased to exist since the building of the Southern Pacific Railway through the basin. The drainage ditches along the right of way are occupied by grassy wash association plants and mammals, thus making one panmictic breeding unit of many small populations that previously were isolated by the creosote bush association.

Three of the four characteristic and most abundant species of the grassy wash association, *Peromyscus leucopus, Reithrodontomys megalotis,* and *Sigmodon hispidus,* never have been recorded from the creosote bush association. Extensive trapping in this association within a few hundred feet of the grassy wash association when population pressure was at a peak there failed to take a single individual of any of these species. All are closely associated with grass and other heavy ground cover in the southwestern desert regions, and *Sigmodon* is conspicuously adapted morphologically to such an environment. For these species, the creosote bush association, consequently, affords an effective barrier to dispersal.

One species, *Peromyscus maniculatus,* which is characteristic of the grassy wash association and abundant there, occurs but rarely in the creosote bush association. For this species, and for the three discussed above, there can be little doubt that the creosote bush association acts as a highly effective, although probably not complete, barrier to dispersal.

Where units of grassy wash association are surrounded by the mesquite association, the isolation of these units apparently is less effective than where they are surrounded by creosote bush association. For *Peromyscus maniculatus* the mesquite association is no barrier, because this species is one of the characteristic and abundant species there. For *Peromyscus leucopus* and *Sigmodon hispidus* this association is a partial barrier, which is most effective for the latter. *Sigmodon* was taken rarely in the mesquite association and only at a time when a peak population existed in the grassy wash association. *Peromyscus leucopus* was fairly common locally in the mesquite association when populations were high, and a few were found locally even when populations were not at a peak. *Reithrodontomys megalotis* has been recorded from the mesquite association only where there was an unusual variety and abundance of vegetation. The mesquite association, as represented at most places in the Tularosa Basin, apparently is an effective barrier to this species. In general, the evidence indicates that the mesquite association is a highly effective barrier to the dispersal of *Sigmodon* and that this association acts to retard the dispersal of *Peromyscus leucopus* and *Reithrodontomys megalotis.* Even in the case of *Peromyscus* and *Reithrodontomys* this barrier probably is fully adequate to permit random divergence in neighboring populations if Wright's statement (1931: 126) is taken as a rough criterion of the isolation necessary for this to take place.

The mesquite association, in the Tularosa Basin, occurs as rather widely separated units. One such unit is the area of several square miles of mesquite immediately south of Alamogordo. Another, comprising several hundred square miles, occurs on the Escondida red sands. A small unit of only one or two square miles is situated on the quartz sands west of Tularosa. There are other such units in the northern and western parts of the basin. These units are separated by wide expanses of atriplex association, creosote bush association, or both. *Peromyscus maniculatus* and *Neotoma micropus* of the mesquite association seem to find these intervening associations a fairly effective barrier to dispersal. For some of the other species these unfavorable associations probably also are partially effective as barriers, because the species are relatively scarce in them.

Isolation and Differentiation of Mammals on the White Sands

The White Sands comprise approximately 270 square miles of dazzling white gypsum dunes near the middle of the Tularosa Basin. They are surrounded by atriplex association and on the west by an alkali flat that presents even more adverse conditions as a mammalian habitat than does the atriplex association. The mammals of the White Sands are mostly those that occur in abundance in the mesquite association or that are widely distributed in most of the ecological associations of the desert plain. Several of these species, however, are known to occur rarely in the atriplex association, and some of them have not been recorded from that association. Consequently, the rather considerable populations of mammals living at the edge of the White Sands are, to some extent, isolated from populations of the same species living in the distant mesquite association. For example, the White Sands are separated from the Alamogordo mesquite by approximately ten miles of atriplex association. At least two of these species apparently are undergoing adaptive differentiation on the White Sands. A local race of the wood rat (*Neotoma micropus leucophaea*) has been described from the White Sands by Goldman (1933: 472). The describer stated that this is a "slightly differentiated" race, paler than *canescens* of other parts of the Tularosa Basin. The spotted ground squirrel (*Citellus spilosoma major*) is paler and has larger white spots on the White Sands than it does on the darker soil of the mesquite association near Alamogordo (Blair, 1941*b*). The Chihuahua deer-mouse (*Peromyscus maniculatus blandus*) also tends to be paler on the White Sands than in some other populations in the Tularosa Basin. This is shown by a detailed study of color variation of this mouse in the Tularosa Basin now in progress.

Two species of mammals of the White Sands never have been recorded from any other ecological associations of the Tularosa Basin. Significantly, both of these species are represented on the White Sands by endemic races. One of these, *Perognathus apache gypsi,* is extremely pale and, consequently, is well adapted for concealment on the White Sands. The other, *Geomys arenarius brevirostris,* while a well-marked race, is not adaptively colored. Actually, *brevirostris* is darker than another race living on darker soil in the Rio Grande Valley from El Paso to Las Cruces.

Benson (1933: 25) in attempting to explain this anomalous phenomenon stated that these pocket gophers tend to match the wet soil they push out of their burrows. He also said that the pocket gophers are most abundant in low places, where the soil is wet and consequently yellowish. The gypsum sand, when wet, is somewhat darker than when dry, giving an Ives tint photometer reading of 58 per cent for reflected red compared with a value of 70 per cent for the dry sand. The wet sand, however, lacks much of being as dark as the local race of pocket gopher. Two specimens of this animal from the White Sands give an average tint photometer reading of 18.5 per cent for red. A specimen of *Geomys arenarius arenarius* from Kenzin, Dona Ana County, has a tint photometer reading of 21 per cent for red. Both races are relatively pale and tend to match the pale desert soils of southern New Mexico. The fact remains, however, that *brevirostris* is much darker than either the dry or wet gypsum, and it is darker than another race living on darker soil than the gypsum.

The adaptively colored pocket mouse also is darker than either the wet or dry sand and gives a lower mean tint photometer value (see Dice and Blossom, 1937: 79). The difference, however, between the mean pelage color of the pocket mice and the mean color of the dry sand is considerably less than that between the pocket gopher and even the wet sand. The palest pocket mice approach the light color of the sand much more closely than do any of the pocket gophers. Actually, the tint photometer readings of the pocket mice do not show adequately the full extent of the adaptive coloring of these animals, for the readings are made on the dorsal stripe, which is the darkest part of the animal.

Benson's statement that the *Geomys* are exposed to attack when on the soil shoved out of their burrows, and his inference that selection is toward a pelage that matches this soil is scarcely defensible. In the interior of the White Sands the species is very abundant in the dry valley association, where the sand is dry and white. Trails in the sand indicate that the pocket gophers often leave their burrows and travel overland for several feet to gather food. Many of the burrows have these trails radiating out in several directions from them. It can hardly be doubted that the animals are more exposed to attack when several feet from their burrows than when they are at the entrances to them.

The endemic race of *Geomys* on the White Sands apparently has originated through random differentiation in an isolated population, for its principal characteristics are cranial and presumably nonadaptive. The failure of this pocket gopher to have developed a pelage in harmony with the light background suggests that colonization of the White Sands by *Geomys arenarius* has been a rather recent event. The relatively dark color of this race possibly was fixed before the species invaded the White Sands. The White Sands are on the extreme periphery of the range of the genus and species, and an extension of the geographic range may well have occurred in comparatively recent time. Pocket gophers, as a group, match rather closely the soil on which they occur. This being the case, it is logical to believe that *Geomys* has inhabited the White Sands too short a time to become adaptively colored. The Escondida red sands, which extend southward into Texas, afford a logical invasion route from the population of *Geomys arenarius* inhabiting the Rio Grande Valley. This species was trapped in a very similar sand area at Kenzin. If, as I believe, the Escondida sands have been the avenue by which *Geomys* reached the White Sands the species apparently later became extirpated there, for there are no records of *Geomys* from there.

One cannot but note that, in spite of its lack of protective coloration, *Geomys* is one of the most abundant species of mammals on the White Sands. Since pocket gophers spend much more time underground than do most small mammals they undoubtedly are less subject to attack by predators than are the other forms. This being the case, natural selection theoretically should operate more slowly in bringing the pelage of these subterranean mammals into harmony with their environment than it would operate on species that spend much of their time above ground. Nevertheless, in the course of future evolution, natural selection theoretically should produce a pale race of *Geomys* on the White Sands.

In general, species of mammals that appear to be completely isolated on the White Sands are represented there by well-marked endemic races. One of these races, *Perognathus apache gypsi,* is adaptively modified; the other, *Geomys arenarius brevirostris,* apparently represents random differentiation. Some of the species that are partly isolated from other populations in the basin by the unfavorable atriplex association exhibit a trend toward adaptive differentiation on the White Sands. No detailed comparisons between populations of most of the partly isolated species have been made.

Isolation and Differentiation of Mammals on the Malpais Lava

The striking examples of protectively colored mammals to be found on the malpais lava bed already have been discussed in detail (Bradt, 1932; Benson, 1933; and Dice and Blossom, 1937). Five endemic races, characterized by dark pelages that somewhat match the dark lava rock, have been described. In addition, *Peromyscus eremicus* is represented by a variable population in which a fairly high percentage of the animals are dark. The one specimen of *Eutamias cinereicollis* known from the association was stated by Benson (1933) to be dark. Thus, seven species have undergone or appear to be undergoing adaptive differentiation on the malpais lava.

Previous workers have attributed the development of the dark races on the malpais lava to the combined effects of isolation and natural selection, with which view I am in accord. It should be emphasized, however, that the isolation of these species on the malpais lava is far from complete. All of these species are abundant in the mountains that border the Tularosa Basin, and in one place, according to Bradt (1932), the malpais is in contact with the foothills of these mountains. The malpais is very close to these hills along much of its western edge. Furthermore, there are scattered hills only a few miles apart between the eastern edge of the malpais and the mountains. Four of the species that are differentiated on the malpais have been taken in desert associations of the basin. Individuals of these species, which include *Citellus variegatus, Peromyscus eremicus, Peromyscus nasutus,* and *Neotoma albigula,* easily could reach the malpais from the hills to the west or from the mountains to the east by way of the scattered hills and buttes. They could come from either direction by crossing two or three miles or less of desert between areas of favorable ecological conditions. All four of these species have been found in desert associations at least two or three miles from the mountains. It probably is significant, as Benson (1933) has pointed out, that *Peromyscus eremicus,* which is the most variable of the differentiated lava bed mammals, occurs in desert associations in greater numbers and farther from the mountains than do the other species. It seems likely that more individuals of *eremicus* than of the other species reach the malpais from near-by areas of light rock.

Briefly, the development on the malpais of dark races of species of which relatively light races occupy the near-by mountains indicates that natural selection is sufficiently rigorous there to produce adaptive differentiation. The evolution of these dark races has occurred and is occurring in spite of the fact that the malpais populations are only partly isolated. No measure of the interchange of individuals of any species between the malpais population and the populations of near-by hills has yet been made. The close proximity to hills along much of the malpais suggests that there probably is a sufficient interchange of individuals to prevent random divergence of the populations, if the general statement of Wright (1931: 126) is taken as a rough indication of the amount of interchange necessary. That differentiation has taken place and is taking place apparently is due to selection pressure sufficiently strong to neutralize and to overcome the effect of incoming genes.

Associations of the Desert Plain as Barriers to Mammals of the Mountains

The slopes of the mountains near the Tularosa Basin and isolated buttes in the basin are inhabited by several species of mammals that are more or less restricted to rocky situations. Others, while not rock inhabitants, are largely restricted to the ecological associations of the mountain slopes. The desert plain of the Tularosa Basin is, in part at least, a barrier to the dispersal of these species. That the Tularosa Desert is not a complete barrier to several of these mammals is indicated by the fact that seven of them have been recorded from the ecological associations of the desert, at least two or three miles from the nearest rocky situations at the base of the mountains. *Citellus variegatus* was observed in the creosote bush association, and Dice (1930) recorded it from the mesquite association. *Peromyscus truei* was trapped in the creosote bush and grassy wash associations. *Peromyscus eremicus* and *Neotoma albigula* were taken in the mesquite and grassy wash associations. *Peromyscus nasutus* was taken in the grassy wash association. Tracks of *Odocoileus* species were seen in the mesquite association and on the White Sands. Remains of *Erethizon epixanthum* were found on the White Sands. Of all these species, *Peromyscus eremicus* occurs on the desert in greater numbers than does any other of these species and has been recorded farthest from the mountains. Nine individuals of this species were trapped in mesquite association near the middle of the basin. At the time when most of these species of small mammals were trapped on the desert, the fall of 1938, populations were at a peak. Population pressure must then have been heavy in their normal habitats.

Although these several species of saxicolous mammals of the mountain slopes have been taken in the Tularosa Desert, it seems certain that isolation of scattered buttes in the center of the basin by the desert associations must be highly effective, except for *Peromyscus eremicus*. Benson (1933) recorded *Perognathus intermedius, Peromyscus eremicus,* and *Neotoma albigula,* from Cerrito Tularosa, an isolated, rocky peak southwest of Tularosa. There probably is some interchange of genes between the population of this peak and the populations of other similar, partly isolated peaks and buttes such as the Tres Hermanos group southwest of Alamogordo. There probably is also some transfer of characters between these desert butte populations and the populations of the mountains that front on the desert. This interchange, however, appears to be too slight to prevent theoretically random divergence in the partly isolated populations.

SUMMARY

Four major ecological associations occupy the desert plain in the Tularosa Basin. Four other ecological associations are recognized on the White Sands, and the malpais lava comprises still another association. In the Tularosa Basin certain species of mammals are largely restricted to the grassy wash or mesquite association, and they occur only rarely in the creosote bush and atriplex associations. The unfavorable creosote bush and atriplex associations, consequently, somewhat isolate the populations of neighboring, scattered areas of the grassy wash and mesquite associations. Thus, there are, in the Tularosa Basin, numerous relatively small populations of mammals that appear to be sufficiently isolated to permit theoretically random divergence in their genetic constitutions.

Several desert species of mammals appear to be developing adaptively modified races on the White Sands, where they are partly isolated by the atriplex association. Two species that apparently are completely isolated on the White Sands are well differentiated there. One of these is protectively colored; the other seems to represent random differentiation.

Seven species of mammals have undergone or appear to be undergoing adaptive differentiation on the malpais lava. These populations are but little isolated from the populations of near-by mountains and hills. Therefore, selection on the malpais lava appears to be sufficiently rigorous to overcome the nullifying effects of a considerable interchange of individuals between this and neighboring populations.

The Tularosa Desert serves to isolate populations of saxicolous mammals living on scattered buttes in the desert and in the mountains bordering it. That this isolation is not complete is indicated by the fact that seven species of mammals usually restricted to rocks and mountain slopes have been recorded from the desert.

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